





Chapter 14: Navigation

Overview

Introduction

The art and science of navigation is an ancient skill. For thousands of years sailors navigated by using the stars as their guide. In the distant past only a select few were allowed access to the 'mysteries' of navigation for possession of them gave one considerable power. A person who could safely follow the stars and navigate a ship - from one point to another - exercised significant influence over crew members who could not.

The art of navigation has expanded from using the stars and planets (celestial navigation) to sophisticated electronic systems (electronic navigation). The safe and confident navigation of your boat - is an absolute necessity, not only for the welfare of your fellow crew members - but also for the welfare of those you are sent to assist. Boat navigation falls into three major categories:

- Piloting: use of visible landmarks and aids to navigation as well as by soundings.
- Dead Reckoning: by true or magnetic course steering and using speed to determine distance traveled from a known point in a known period.
- Electronic Navigation: by radio bearings, Loran, GPS, and other electronic systems.

As a coxswain, you are responsible for knowing the position of your boat at all times. Additionally, you have been entrusted with the safety of your boat, all crew members, and people from distressed vessels.

Each crew member on a Coast Guard boat is a coxswain in training. If you are a crew member, you must learn all landmarks, charts and navigation aids used for the waters where you are operating. Through experience, you will become proficient in the various skills necessary to perform any essential task in an emergency.



In this chapter

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Section A. The Earth and Its Coordinates

Overview

Introduction

Navigation is concerned with finding your position and calculating distances measured on the surface of the earth which is a sphere. However, the earth is not a perfect sphere - the diameter through the equator is about 23 nautical miles longer than is the diameter through the North and South Poles. This difference is so small that most navigational problems are based on the earth being a perfect sphere. Charts are drawn to include this slight difference. Distance is figured from certain reference lines. Your position at any given time, while underway, may be determined by your location relative to these lines as well as visible landmarks in your local area. You must know what these lines are - and how to use them.

In this section

These items are discussed in this section:

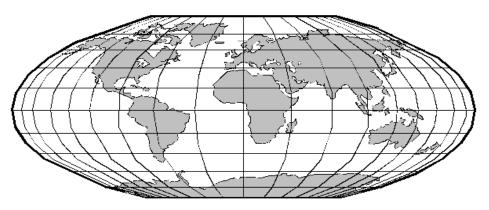
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Lines and Circles

A.1. Reference lines of the earth

The earth rotates around an axis, this axis may be defined as a straight line drawn through the center of the earth. The axis line meets the surface of the earth at the North Pole and at the South Pole. To determine your location, a system of reference lines is placed on the surface of the earth as shown in Figure 14-1. This figure reveals the difficulty a boat navigator faces - the earth is curved as a sphere but navigation is typically done on a flat chart with straight reference lines running top to bottom and left to right.



Earth with Reference Lines Figure 14-1

A.2. Great circles

A great circle is a geometric plane passing through the center of the earth which divides the earth into two equal parts. A great circle always passes through the 'widest' part of the earth. The equator is a great circle. All circles that pass through both the North and South Poles are great circles. The edge of a great circle conforms to the curvature of the earth. Just as if you look up at a full moon you see a circle.

NOTE &

The earth's circumference is 21,600 nautical miles. You determine a degree of arc on the earth's surface by dividing the earth's circumference (in miles) by 360 degrees



A.2.a. Circle properties

The outline of the moon also reveals another fact about great circles which is a property of all circles: each circle possesses 360 degrees around its edge, which passes through a sphere - so as to divide the sphere into two equal half-spheres. There are an infinite number of great circles on a sphere.

A.2.b. Degrees

Great circles have 360 degrees of arc. In every degree of arc in a circle there are 60 minutes. 60 minutes is equal to one degree of arc and 360 degrees are equal to a complete circle. When degrees are written, the symbol (°) is used.

A.2.c. Minutes

For every degree of arc, there are 60 minutes. When minutes of degrees are written, the symbol (') is used, 14 degrees and 15 minutes is written: $14^{\circ}15'$.

When written, minutes of degrees are always expressed as two digits. Zero through nine minutes are always preceded with a zero. Three minutes and zero minutes are written as 03' and 00' respectively.

A.2.d. Seconds

For every minute of arc, in a circle, there are 60 seconds of arc. 60 seconds is equal to one minute of arc - and 60 minutes is equal to one degree of arc.

For every minute of arc there are 60 seconds. When seconds are written the symbol (") is used. 24 degrees 45 minutes and 15 seconds is written: 24°45'15".

When seconds are written they are always expressed as two digits. Zero through nine seconds are always preceded with a zero. Six seconds and zero seconds are written as 06" and 00" respectively.

Seconds may also be expressed in tenths of minutes. 10 minutes, 6 seconds (10'06") can be written and 10.1'.

The relationship of units of "arc" can be summarized as follows:

Circle =	360 degrees (°)
1 degree (°) =	60 minutes (')
1 minute (') =	60 Seconds (")



Parallels

A.3. General

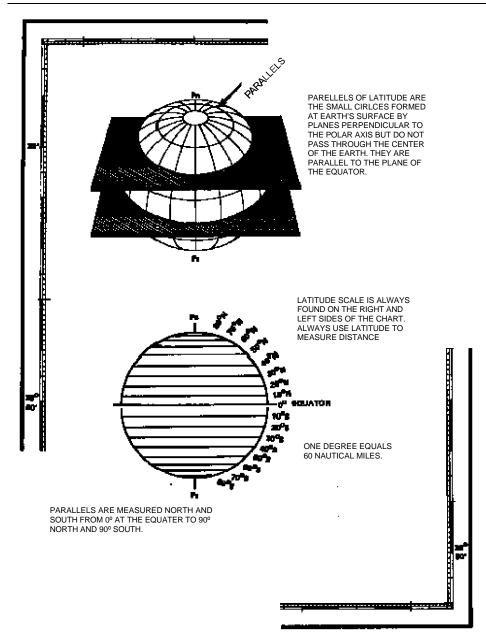
Parallels are circles on the surface of the earth moving from the Equator to the North or South Pole. They are parallel to the Equator and known as Parallels of Latitude, or just latitude.

Parallels of equal latitude run in a West and East direction (left and right on a chart). They are measured in degrees, minutes, and seconds, in a north and south direction, from the equator. (0 Degrees at the equator to 90 degrees at each pole).

The North Pole is 90 degrees North Latitude - and the South Pole is 90 degrees South Latitude. The equator itself is a special parallel because it is also a great circle. One degree of latitude (arc) is equal to 60 nautical miles (NM) on the surface of the earth, one second (") of latitude is equal to 1 NM. The circumference of the parallels decrease as they approach the poles. (See Figure 14-2)

On charts of the northern hemisphere, True North is usually located at the top. Parallels are normally indicated by lines running from side to side - while the latitude scales are normally indicated along the side margins - by divisions along the black-and-white border as shown in the upper left and the lower right margins of Figure 14-2.





Parallels of Latitude Figure 14-02

A.4. To measure latitude

To measure the latitudinal position of an object on a nautical chart follow the procedure as follows:



NOTE &

•	Always use the
	latitude scale to
	measure
	distance in
	navigation.

 A degree of latitude is measured 'UP' or 'DOWN'

Step	Procedure	
1	Put one point of a pair of dividers on the parallel of latitude	
	nearest to the object.	
2	Place the other point of the dividers on the object.	
3	Move the dividers to the nearest latitude scale, keeping the	
	same spread on the dividers.	
4	Place one point on the same parallel of latitude that you used	
	before (STEP No. 1). The second point of the dividers will	
	fall on the correct latitude of the object.	
5	Read the latitude scale.	

NOTE &

On a mercator projection chart (normally used for boat navigation), the scale varies along the latitude scale but will always remain accurate in relation to actual distance within the latitude bounded by that scale.



Meridians

A.5. General

CAUTION!

A degree of longitude is equal to 60 miles at the equator. This is why PARALLELS of LATITUDE are used to measure distance in navigational problems.

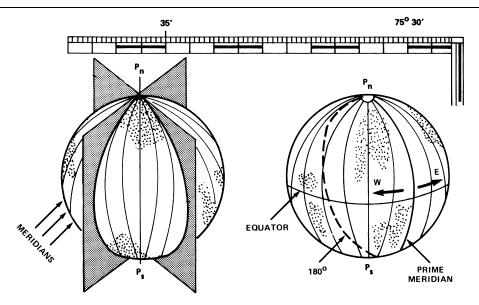
A meridian is a great circle formed by a plane which cuts through the earth's axis and its poles. Such circles are termed meridians of longitude.

The meridian which passes through Greenwich, England, by international convention, has been selected as 000 degrees and is called the Prime Meridian. From this point, Longitude is measured both East and West for 180 degrees.

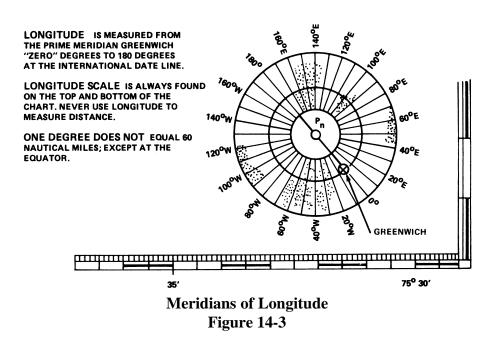
The 180 degree meridian is on the exact opposite side of the earth from the 000 degree meridian. The International Date Line generally conforms to the 180th meridian. The great circle of the Prime Meridian and the International Date Line divide the earth into eastern and western hemispheres.

A degree of longitude equals 60 miles at the equator and is undefined at the poles since all meridians meet at one point there Meridians of Longitude run in a North and South direction (top to bottom on a chart) and are measured in degrees, minutes and seconds, in an East or West direction. (See Figure 14-3)





MERIDIANS OF LONGITUDE ARE FORMED ON THE EARTH'S SURFACE BY GREAT CIRCLES WHICH PASS THROUGH THE NORTH AND SOUTH POLES AND ARE MEASURED EAST AND WEST.



A.6. To measure longitude

To measure the longitude of an object on a nautical chart, follow the same procedures as in measuring a latitude position using the longitude scale.



A.7. Rhumb line

Typical boat navigation is done by plotting rhumb lines on a Mercator chart. A rhumb line is an imaginary line that intersects all meridians at the same angle. The rhumb line on the surface of a sphere - is a curved line. On most nautical charts this curved line (rhumb) is represented as a straight line.

A course line, such as a compass course, is a rhumb line which appears as a straight line on a mercator chart. Navigating with a rhumb line course allows the helmsman to steer a single compass course.



Chart Projections

A.8. General

For the purpose of coastal navigation, the earth is considered to be a perfect sphere. To represent the features of the earth's spherical surface on the flat surface of a chart, a process termed 'projection' is used. Two basic types of projection used in making piloting charts are Mercator and Gnomonic.

A.9. Mercator projection

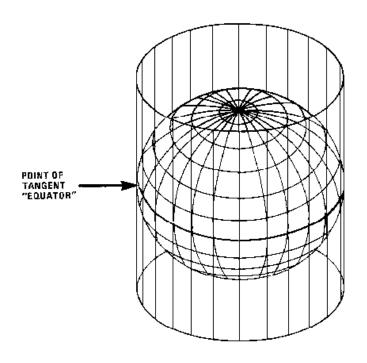
Mercator charts are the primary charts used aboard boats. A mercator projection is made by transferring the surface of the globe (representing the earth) onto the cylinder.

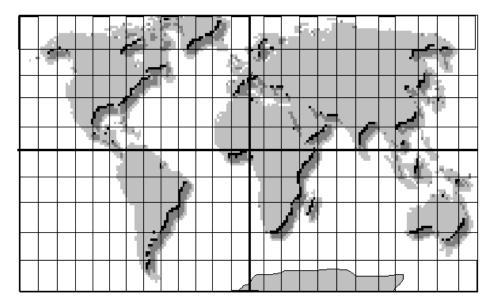
NOTE &

Only the latitude scale is used for measuring distance.

The equator is the reference point for accomplishing the 'projection' from one geometric shape to another. The distinguishing feature of the mercator projection is that the meridians are projected so they appear to be equal distance from each other and parallel. (See Figure 14-4)







Mercator Projection Figure 14-4



A.10. Gnomonic projection

NOTE &

Gnomonic projections aid in long distance navigation by allowing navigators to use great circle courses. Meridians appear as straight lines that converge as they near the closest pole. The equator is represented by a straight line, all other parallels appear as curved lines.

Gnomonic charts are not normally used for boat navigation.



Section B. Nautical Charts

Overview

Introduction

The nautical chart is one of the mariner's most useful and most widely used national aids. Navigational charts contain a lot of information of great value to you as a boat coxswain.

In this section

These items are discussed in this section:

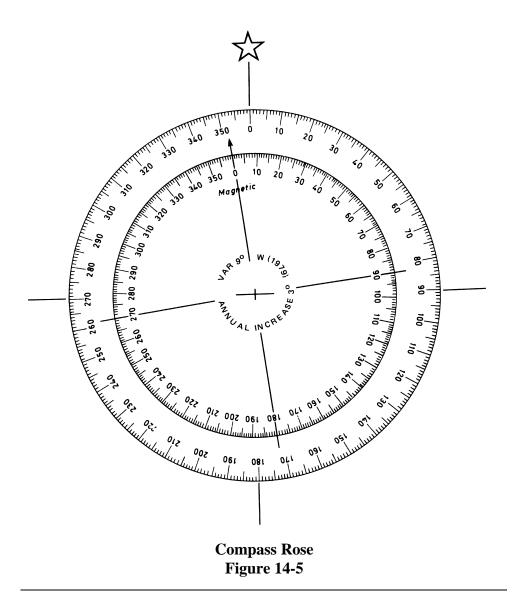
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The Compass Rose

B.1. General

Nautical charts usually have one or more compass roses printed on them. These are similar in appearance to the compass card and, like the compass card, are oriented with North at the top. Directions on the chart are measured by using the compass rose (See Figure 14-5). Direction is measured as a straight line from the center point of the circle to a number on the compass rose. Plotting the direction and explanation of the terms is discussed later.





B.2. True direction is printed around the outside of the compass rose. B.3. Magnetic direction is printed around the inside of the compass rose. An arrow points to magnetic North. B.4. Variation Variation, the difference between true and magnetic north, for the particular area covered by the chart is printed in the middle of the

compass rose (as well as any annual change).



Soundings

B.5. General

One of the more vital services a chart performs is to describe the bottom characteristics to a boat operator. This is accomplished through the use of combinations of numbers, color codes, underwater contour lines and a system of symbols and abbreviations.

B.6. Datum

The nautical chart water depth is measured downward from sea level at low water (soundings). Heights or landmarks are given in feet above sea level. In the interest of navigation safety the mean, or average, of the lower - of the two tides in the tidal cycle is used for soundings.

B.6.a. Mean low tide

Most of the numbers on the chart represent soundings of the water depth at Mean Low Tide. Datum refers to a base line from which a chart's vertical measurements are made.

B.6.b. Mean low water

On the East and Gulf Coasts the tidal datum is Mean Low Water (the average Low tide). The tidal cycle on the East and Gulf Coasts produces tides approximately equal in highness and lowness.

B.6.c. Average low tide

Since the greatest danger to navigation is during low tide, a number of the depths of low tide are averaged to produce the Average Low tide.

B.6.d. Mean low water mark

On the Pacific Coast the datum is the mean lower low water mark. The reason for the mean lower of the two low tides being the west coast datum is because their low tides can differ by several feet.

B.7. Color code

Generally, the shallow water is tinted darker blue on a chart, while deeper water is tinted light blue or white.

B.8. Contour lines

Contour Lines, also called fathom curves, connect points of roughly equal depth and provide a profile of the bottom. These lines are either numbered or coded, according to depth, using particular combinations of dots and dashes.



B.8.a. Equating depth

Depth of water may either be in feet, meters or fathoms (a fathom equals six feet). The chart legend will indicate which unit (feet, meters or fathoms) is used.



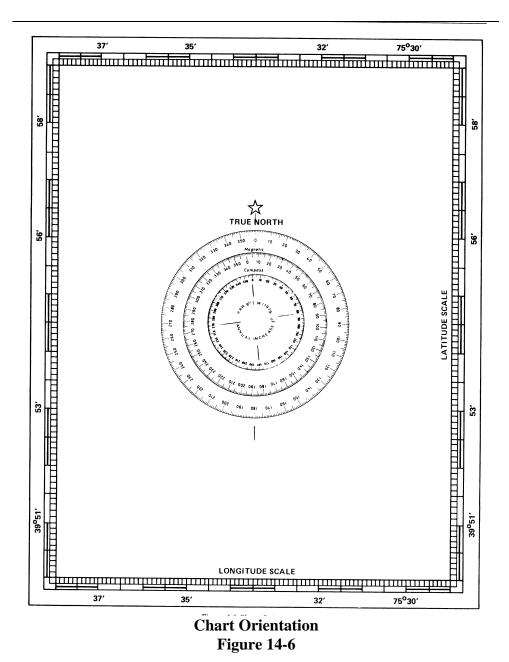
Basic Chart Information

B.9. General

The nautical chart shows channels, depth of water buoys, lights, lighthouses, prominent landmarks, rocks, reefs. sandbars, and much more useful information for the safe piloting of your boat. The chart is the most essential part of all piloting equipment. Below are some basic facts you should know about charts:

- Charts are oriented with North at the top.
- The frame of reference for all chart construction is the system of latitude and longitude.
- Any location on a chart can be expressed in terms of latitude or longitude. (See Figure 14-6)
 - The latitude scale runs along both sides of the chart.
 - The longitude scale runs across the top and bottom of the chart.
 - Latitude lines are reference points in a North and South direction with the equator as their zero reference point.
 - Longitude lines are the East and West reference points with the prime meridian as their zero reference point.



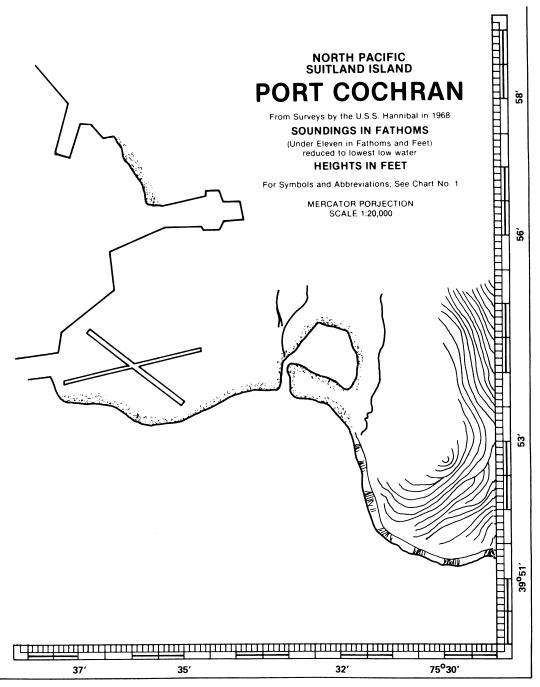


B.10. General information block

The general information block (See Figure 14-7) contains these items:

- The chart title which is usually the name of the prominent navigable body of water within the area covered in the chart;
- A statement of the type of projection and the scale; and
- The unit of depth measurement (feet, meters or fathoms).





Title Block of a Chart Figure 14-7



B.11. Notes

Closely read the notes. They may contain information that can not be presented graphically, such as:

- The meaning of abbreviations used on the chart;
- Special notes of caution regarding danger;
- Tidal information; and
- Reference to anchorage areas.

B.12. Edition number

The edition number of a chart and latest revisions tell you when information on the chart was updated.

- The edition number and date of the chart is located in the margin of the lower left hand corner.
- The latest revision date immediately follows in the lower left hand corner below the border of the chart. Charts show all essential corrections concerning lights, beacons, buoys and dangers which have been received to the date of issue.

Corrections occurring after the date of issue are published in the Notice to Mariners and must be entered by hand on the chart of your local area upon receipt of the notice.



Scale of the Nautical Chart

B.13. General

The scale of a nautical chart is the ratio - comparing a unit of distance on the chart to the actual distance on the surface of the earth.

NOTE &

Navigate with the largest scale chart available.

For example: The scale of 1:5,000,000 means that one of some kind of measurement of the chart is equal to 5,000,000 of the same kind of measurement on the earth's surface. One inch on the chart would equal 5,000,000 inches on the earth's surface. This would be a small scale, chart, since the ratio 1/5,000,000 is a very small number.

"Large scale" chart represents a smaller area than that of a 'small scale' chart. There is no firm separation between 'large scale' and 'small scale'. Remember 'large scale - small area', and 'small scale - large area'.

For example: The scale of 1:2,500 (one inch on chart equals 2,500 inches on the earth's surface) is a much larger number and is referred to as a large scale chart.

B.14. Sailing charts

Sailing Charts are produced at scales of 1:600,000 and smaller. They are used in fixing the mariners position - for approach to the coast - from the open ocean, or for sailing between distant coastal ports.

On such charts, the shoreline and topography are generalized; only off shore soundings, such as the principal lights, outer buoys and landmarks visible at considerable distances are shown.

B.15. General charts

General Charts are produced at scales between 1:150,000 and 1:600,000. They are used for coastwise navigation outside of outlying reefs and shoals when the ship or boat is generally within sight of land or aids to navigation and its course can be done by piloting techniques.

B.16. Coastal charts

Coastal Charts are produced at scales between 1:50,000 and 1:150,000. They are used for inshore navigation, for entering bays and harbors of considerable width, and for navigating large inland waterways.

B.17. Harbor charts

Harbor Charts are produced at scales larger than 1:50,000. They are used in harbors, anchorage areas, and the smaller waterways.



B.18. Small craft charts

Small Craft Charts are produced at scales of 1:40,000 and larger. There are special charts of inland waters, including the Intracoastal Waterways. Special editions of conventional charts, called small craft charts, are printed on lighter weight paper and folded.

These 'SC' charts contain additional information of interest to small craft operators, such as data on facilities, tide predictions, and weather broadcast information.



Chart Symbols and Abbreviations

B.19. General

Many symbols and abbreviations are used in charts. It is a quick way to tell you the physical characteristics of the charted area and information on aids to navigation.

These symbols are uniform and standardized, but may vary depending on the scale of the chart or chart series. These standardized chart symbols and abbreviations are shown in the Pamphlet 'CHART No. 1' published jointly by the Defense Mapping Agency Hydrographic Center and the National Ocean Service.

B.20. Color

Nearly all charts employ color to distinguish various categories of information such as shoal water, deep water, and land areas. Color is also used with aids to navigation (ATON) to make them easier to locate and interpret.

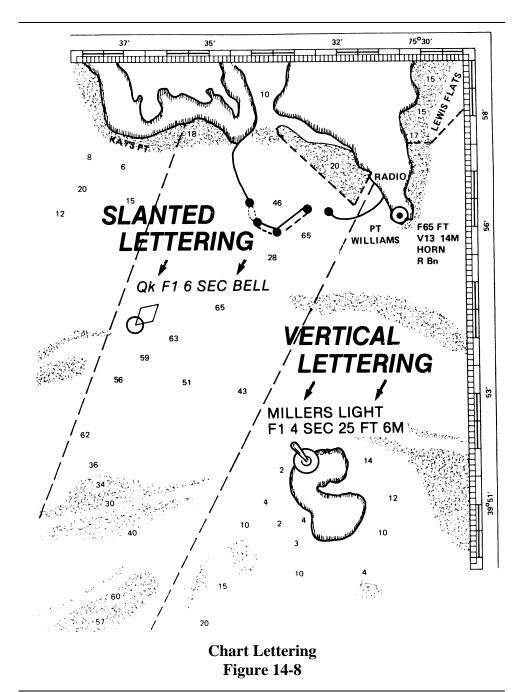
Nautical purple ink (magenta) is used for most information since it is easier to read under red light normally used for navigating at night.

B.21. Lettering

Lettering on a chart provides valuable information. Slanted Roman lettering on the chart is used to label all information that is affected by tidal change or current (with the exception of bottom soundings). All descriptive lettering for floating ATON is found in slanted lettering.

Vertical roman lettering on the chart is used to label all information that is not affected by the tidal changes or current. Fixed aids such as lighthouses and ranges are found in vertical lettering. (See Figure 14-8)





14-27



Buoy Symbols

B.22. Symbol description

Buoys are shown with the following symbols:

- The basic symbol for a buoy is a diamond and small circle.
- A dot will be shown instead of the circle on older charts.
- The diamond may be above, below or alongside the circle or dot.
- The small circle or dot denotes the approximate position of the buoy mooring.
- The diamond is used to draw attention to the position of the circle or dot and to describe the aid.

See Chapter 13 *Aids to Navigation*, for ATON chart symbols, additional information and color pictures of ATON.



Other Chart Symbols

B.23. Lighthouses and other fixed lights

The basic symbol is a black dot with a magenta 'flare' giving much the appearance of a large exclamation mark (!). Major lights are named and described; minor lights are described only.

B.24. Ranges and beacons

Chapter 13 *Aids to Navigation*, has chart symbols and color pictures of these ATON.

B.24.a. Ranges

Ranges are indicated on charts by symbols for the lights (if lighted) and dashed line indicating the direction of the range.

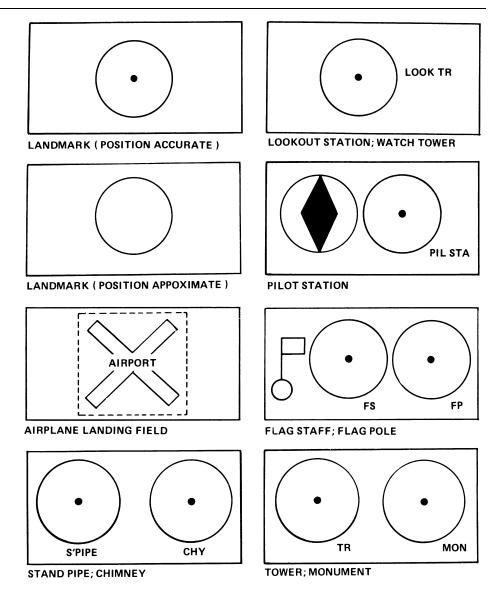
B.24.b. Day beacons

Day beacons are indicated by small triangles, which may be colored to match the aid. Day beacons, also commonly called day marks are always fixed aids. That is, they are on a structure secured to the bottom or on the shore. They are of many different shapes.

B.25. Prominent landmarks

Prominent landmarks such as water towers, smoke stacks, and flag poles are pinpointed by a standard symbol of a dot surrounded by a circle. A notation next to the symbol defines the landmark's nature. The omission of the dot indicates the location of the landmark is only an approximation. (See Figure 14-9)



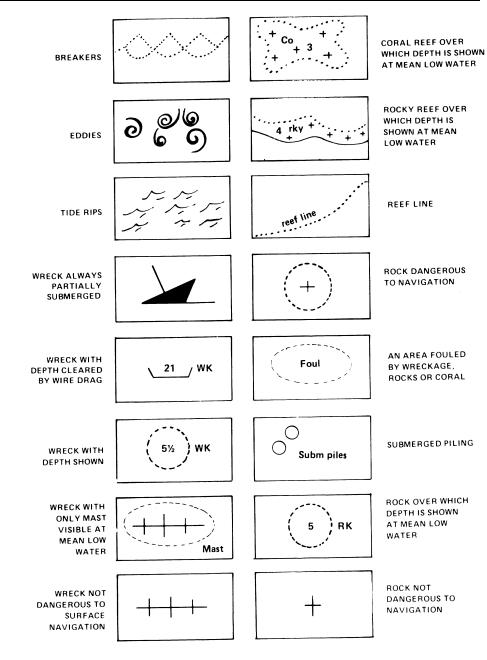


Symbols for Prominent Landmarks Figure 14-9

B.26. Wrecks, rocks, and reefs

These are marked with standardized symbols, for example, a sunken wreck may be shown either by a symbol or by an abbreviation plus a number that gives the wreck's depth at mean low or Lower low water. A dotted line around any symbol calls special attention to its hazardous nature. (See Figure 14-10)





Breakers, Rocks, Reefs, Pilings Figure 14-10



B.27. Bottom characteristics

A system of abbreviations, used alone or in combination, describes the composition of the bottom allowing you to select the best holding ground for anchoring. (See Figure 14-11)

NOTE &

Knowledge of bottom quality is very important in determining an anchorage.

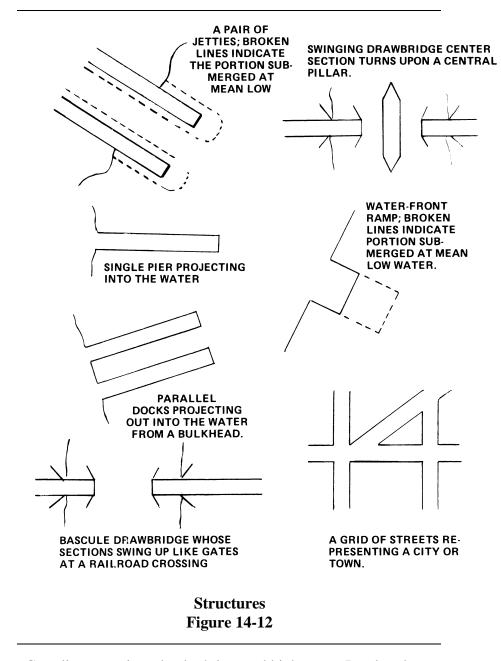
hre	Hard	M	Mud; Muddy
Sft	Soft	G	Gravel
S	Sand	Stk	Sticky
Cl	Clay	Br	Brown
St	Stone	Gy	Gray
Co	Coral	Wd	Seaweed
Co Hd	Coral Head	Grs	Grass
Sh	Shells	Oys	Oysters

Bottom Composition Figure 14-11

B.28. Structures

Shorthand representations have been developed and standardized for low-lying structures such as jetties, docks, drawbridges and waterfront ramps. Such symbols are drawn to scale and viewed from overhead. (See Figure 14-12)

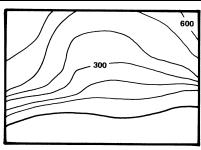




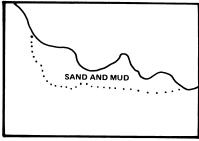
B.29. Coastlines

Coastlines are viewed at both low and high water. Landmarks that may help you fix your position are noted and labeled. (See Figure 14-13)

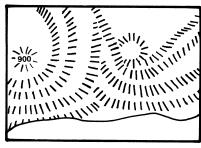




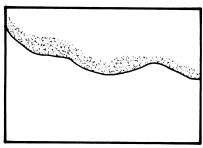
COASTAL HILLS; CONTOURS LINES INDICATES ELEVATIONS.



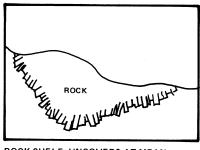
SAND AND MUD FLATS, THAT ARE EXPOSED AT MEAN LOW WATER.



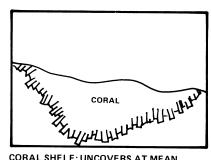
STEEP INCLINED COASTLINE; HACHURES (HATCH) MARKS ARE DRAWN IN THE DIRECTION OF THE SLOPES.



SANDY SHORE, THAT IS EXPOSED AT MEAN LOW WATER.



ROCK SHELF; UNCOVERS AT MEAN LOW WATER.



CORAL SHELF; UNCOVERS AT MEAN LOW WATER.

Coastlines Figure 14-13



Accuracy of Charts

B.30. General

A chart is only as accurate as the survey on which it is based. Major disturbances such as hurricanes and earthquakes, cause sudden and extensive changes in the bottom contour. Even everyday forces of wind and waves cause changes in channels and shoals. The prudent sailor must be alert to the possibilities of changes in conditions and inaccuracies of charted information.

B.31. Determining accuracy

Compromise is sometimes necessary in chart production as various factors may prevent the presentation of all data that has been collected for a given area. The information shown must be presented so that it can be understood with ease and certainty.

In order to judge the accuracy and completeness of a survey, note the following:

B.31.a. Source and date

The source and date of the chart are generally given in the title along with the changes that have taken place since the date of the survey. The earlier surveys often were made under circumstances that precluded great accuracy of detail.

B.31.b. Testing

Until a chart based on such a survey, is tested, it should be regarded with caution. Except in well-frequented waters, few surveys have been so thorough as to make certain that all dangers have been found.

B.31.c. Full or sparse soundings

Noting the fullness or scantiness of the soundings is another method of estimating the completeness of the survey, but it must be remembered that the chart seldom shows all soundings that were obtained. If the soundings are sparse or unevenly distributed, it should be taken for granted, as a precautionary measure, that the survey was not in great detail.

B.31.d. Blank spaces among soundings

Large or irregular blank spaces among soundings mean that no soundings were obtained in those areas. Where the nearby soundings are 'deep', it may logically be assumed that in the blanks the water is also deep. When the surrounding water is 'shallow', or if the local charts shows that reefs are present in the area, such blanks should be regarded with suspicion. This is especially true in coral areas and off rocky coasts. These areas should be given wide berth.

